PATENT APPLICATION

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In re application of
Yuji Kurokawa *et al.*
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For: LIGHT DIFFUSING SHEET AND BACKLIGHT UNIT USING THE LIGHT DIFFUSING UNIT

STATEMENT

Commissioner for Patents
Alexandria, VA 22313-1450

Sir/Madam:

I, Hidetaka Ota, residing at Toranomon East Bldg., 8F, 7-13, Nishi-Shimbashi 1-chome, Minato-ku, Tokyo, Japan hereby state that:

I well understand the Japanese and English languages and attached is an accurate English translation made by me of Japanese Patent Application No. 2004-051017, filed February 26, 2004.

Date : November 12, 2008

Name :
Hidetaka Ota

[Designation of Document] CLAIMS

[Claim 1] A light diffusing film comprising a light-transmitting resin, characterized by having fine recesses formed in at least one of the surfaces thereof, the fine recesses having a shape which is any of the shape of an inverted polyangular pyramid, the shape of an inverted truncated polyangular pyramid, the shape of an inverted cone, and the shape of an inverted truncated cone.

[Claim 2] The light diffusing film according to claim 1, characterized by containing a light diffusing agent.

[Claim 3] A light diffusing film which comprises a core layer made of a light-transmitting resin and a surface layer laminated to at least one of the surfaces of the core layer and made of a light-transmitting resin or of a light-transmitting resin containing a light diffusing agent, characterized in that the surface layer has, formed in the surface thereof, fine recesses having a shape which is any of the shape of an inverted polyangular pyramid, the shape of an inverted truncated polyangular pyramid, the shape of an inverted cone, and the shape of an inverted truncated cone.

[Claim 4] The light diffusing film according to claim 3, wherein the core layer contains a light diffusing agent.

[Claim 5] The light diffusing film according to any one of

claims 1 to 4, wherein the bevel between one surface or a surface of a surface layer and each inclined face of each recess having the shape of an inverted polyangular pyramid or inverted truncated polyangular pyramid, or the bevel between that surface and the ridgeline of each recess having the shape of an inverted cone or inverted truncated cone is 15-70°.

[Claim 6] The light diffusing film according to any one of claims 1 to 5, wherein the proportion of the area occupied by the recesses in one surface or a surface of a surface layer is 30-100%.

[Claim 7] The light diffusing film according to any one of claims 1 to 6, wherein the recesses have been formed in an oblique-line arrangement in one surface or a surface of a surface layer.

[Claim 8] A backlight unit characterized by including the light diffusing film according to any one of claims 1 to 7 which has been disposed on a lightguide plate so that that surface of the film which has recesses formed serves as a light emission side.

[Designation of Document] Specification

[Title of the Invention] LIGHT DIFFUSING FILM AND BACKLIGHT UNIT USING THIS LIGHT DIFFUSING FILM

[Field of the Invention]

[0001]

The present invention relates to a light diffusing film to be incorporated in the backlight unit of a liquid-crystal display for notebook type personal computers, personal computer monitors, television receivers, and the like, especially in the backlight unit of the edge light type.

[Background Art]

[0002]

A backlight unit of the general edge light type for liquid-crystal displays is constituted of a lightguide plate having dots for light diffusion printed on the back side thereof, a light source (e.g., a cold cathode fluorescent tube or LEDs) disposed on one or each side of the lightguide plate, a light diffusing film superposed on the lightguide plate, a lens film (prism film) superposed on the light diffusing sheet, etc.

[0003]

One role of the light diffusing film in the backlight unit is to diffuse the light which has passed through the lightguide plate and diffusing plate and thereby prevent the dots on the back side of the lightguide plate and bright lines

of the light source from being visually recognized on the screen of the liquid-crystal display. Another roll of the light diffusing film is to lead the light which has passed through the lightguide plate and has a large brightness peak angle (the angle at which luminance has a peak; it means an angle with the front direction) to the lens film while converting it into diffused light having a smaller brightness peak angle than that in order that the diffused light might be brought to the front direction (the direction perpendicular to the screen of the liquid-crystal display) by the lens film to further heighten luminance.

[0004]

Known as a light diffusing film which plays such roles is a film (sheet) in which projections of a rectangular pyramid shape having a vertex inclined to either of the left and right have been arranged lengthwise/crosswise on the light emission side (patent document 1). This light diffusing film (sheet) has a constitution in which each projection of a rectangular pyramid shape has a difference in bevel between the left-side and right-side inclined faces, and is intended to thereby lead the light which has passed through the lightguide plate and has a large brightness peak angle to the lens film while converting it into diffused light having a smaller brightness peak angle than that.

[Patent Document 1] Japanese Patent No. 2948796

[Disclosure of the Invention]

[Problems to be Solved by the Invention]

[0005]

However, this light diffusing film having projections of a rectangular pyramid shape is difficult to continuously produce by forming a film by melt extrusion and embossing the film with an embossing roll or the like. Practically, products of this light diffusing film must be produced one by one by injection molding, hot-press molding, or the like. There have hence been problems that the light diffusing film has poor productivity and an increased cost and that it is not easy to produce thin films having a thickness of 150 µm or smaller. In addition, the formation of projections of a rectangular pyramid shape regularly arranged lengthwise/crosswise as in this light diffusing film (sheet) has had problems that the projections may cause a moiré or interference fringe, resulting in luminance unevenness.

[0006]

The invention has been achieved in order to overcome the problems described above. An object to be accomplished by the invention is to provide a light diffusing sheet which enables the light from a lightguide plate to be conducted to a lens film for gathering the light after having been converted to diffused light having a small brightness peak angle in order to heighten the luminance of the screen of a liquid-crystal

display, and which generates neither a moiré or interference fringe nor luminance unevenness, and is advantageous also from the standpoints of productivity and cost.

[Means for Solving the Problems]

[0007]

In order to accomplish those objects, the light diffusing film of the invention comprises a light-transmitting resin and is characterized by having fine recesses formed in at least one of the surfaces thereof, the fine recesses having a shape which is any of the shape of an inverted polyangular pyramid, the shape of an inverted truncated polyangular pyramid, the shape of an inverted cone, and the shape of an inverted truncated cone.

[0008]

The other light diffusing film of the invention comprises a core layer made of a light-transmitting resin and a surface layer laminated to at least one of the surfaces of the core layer and made of a light-transmitting resin or of a light-transmitting resin containing a light diffusing agent, and is characterized in that the surface layer has, formed in the surface thereof, fine recesses having a shape which is any of the shape of an inverted polyangular pyramid, the shape of an inverted truncated polyangular pyramid, the shape of an inverted cone, and the shape of an inverted truncated cone.

[0009]

In the light diffusing film of the invention, it is also desirable to incorporate a light diffusing agent into the light diffusing film or to incorporate a light diffusing agent into the core layer of the light diffusing film. Furthermore, it is desirable that the bevel between one surface or a surface of a surface layer and each inclined face of each recess having the shape of an inverted polyangular pyramid or inverted truncated polyangular pyramid or the bevel between that surface and the ridgeline of each recess having the shape of an inverted cone or inverted truncated cone should be 15-70°. Moreover, the proportion of the area occupied by the recesses in one surface or a surface of a surface layer is desirably 30-100%. Further, it is desirable that the recesses should have been formed in an oblique-line arrangement.

[0010]

Moreover, the backlight unit of the invention is characterized by including the above light diffusing film (the light diffusing film as described in any one of claims 1 to 7) which has been disposed on a lightguide plate so that that surface of the film serves as a light emission side.

[Advantages of the Invention]

[0011]

In a light diffusing film in which fine recesses having a shape which is any of the shape of an inverted polyangular

pyramid, the shape of an inverted truncated polyangular pyramid, the shape of an inverted cone, and the shape of an inverted truncated cone have been formed in at least one of the surfaces thereof as in the light diffusing film of the invention, these fine recesses can be easily formed by embossing. This light diffusing film can hence be continuously and efficiently produced by subjecting a film formed by melt extrusion to embossing with an embossing roll or the like. Consequently, the light diffusing film of the invention attains high productivity and a cost reduction as compared with the light diffusing film (sheet) disclosed in patent document 1, which is produced one by one by injection molding or the like. In addition, the light diffusing film can be easily produced in a small thickness.

[0012]

When a light diffusing sheet of the invention that further contains a light diffusing agent is disposed so that that surface of the sheet having recesses formed therein serves as a light emission side, light having a large brightness peak angle emitted from a lightguide plate is diffused by the light diffusing agent, and it is possible to reduce a brightness peak angle of the diffused light to be led to a lens film, according to light refraction due to an inclined face of the recess having a shape which is any of the shape of an inverted polyangular pyramid, and the shape of an inverted truncated

polyangular pyramid, or light refraction due to a taper face of the recesses having a shape which is any of the shape of an inverted cone, and the shape of an inverted truncated cone. Consequently, by bringing this diffused light having a small brightness peak angle to the front direction (the direction perpendicular to the screen of the liquid-crystal display) by the lens film, the luminance of the screen of the liquid-crystal display can be sufficiently heightened. In addition, since light is intensely diffused by the diffusing agent and the fine recesses, the dots on the lightguide plate becomes less apt to be visually recognized, and dot hiding properties are improved, and the generation of a moire or interference fringe can be inhibited.

[0013]

The function of reducing the brightness peak angle of the diffused light emitted from the light diffusing film is remarkable when the bevel between at least one surface (light emission side) of the light diffusing film and each inclined face of each recess having the shape of an inverted polyangular pyramid or inverted truncated polyangular pyramid or the bevel between that surface and the ridgeline of each recess having the shape of an inverted cone or inverted truncated cone is 15-70° and when the proportion of the area occupied by the recesses in one surface (light emission side) is 30-100%. Furthermore, when that bevel is 20-50° and the areal proportion

of the recesses is 90-100%, the function is remarkable.

[0014]

In addition, a light diffusing sheet, at least one surface of which is formed with the fine recesses in an oblique-line arrangement, generates neither a moire or interference fringe nor luminance unevenness.

[0015]

The other light diffusing film of the invention comprises a core layer and, laminated to at least one of the surfaces thereof, a surface layer made of a light-transmitting resin or of a light-transmitting resin containing a light diffusing agent, and this surface layer has the fine recesses formed in the surface thereof. By disposing this light diffusing film so that that surface which has the recesses formed therein serves as a light emission side, the same effects as described above can be obtained.

[0016]

In the case where the surface layers as above are made of a light-transmitting resin containing no light diffusing agent, the following effect is brought about. Even when the core layer of this film contains a light diffusing agent, formation of this film by melt extrusion molding (three-layer coextrusion molding) does not result in the so-called eye mucus phenomenon in which the light diffusing agent adheres to the periphery of the extrusion orifice, because the core layer

is covered by the light-transmitting resin constituting the surface layers. Consequently, the film surfaces can be prevented from bearing streak lines. On the other hand, in the case where the surface layers contain a light diffusing agent, not only light diffusing properties are improved, but also the surface layers can have a reduced coefficient of linear expansion. Consequently, this light diffusing film can be prevented from rumpling, especially after the film is incorporated in a backlight unit and illuminated.

[0017]

As for a backlight unit into which the above-described light diffusing film is incorporated so that it is disposed on the lightguide plate so as for its surface having the recesses formed therein to serve as a light emission side, the light having a large brightness peak angle, which was emitted by the light source (cold cathode fluorescent tube) and has entered into the light diffusing sheet through the lightguide plate, is brought to a direction where the brightness peak angle becomes small by the fine recesses having a shape which is any of the shape of an inverted polyangular pyramid, the shape of an inverted truncated polyangular pyramid, the shape of an inverted cone, and the shape of an inverted truncated cone, to become diffused light having a small brightness peak angle, and is led to the lens film etc. So, this light having a small brightness peak angle is further brought to the front

direction by the lens film, and therefore, the luminance of the liquid-crystal display screen is sufficiently heightened.

[Best Mode for Carrying Out the Invention]

[0018]

Specific embodiments of the light diffusing film according to the invention will be described below in detail by reference to the drawings, but the invention should not be construed as being limited to these embodiments only.

EXAMPLE 1

[0019]

Fig. 1 is a diagrammatic sectional view of a light diffusing film according to one embodiment of the invention, and shows the light diffusing film incorporated in a backlight unit indicated by the imaginary lines. Fig. 2 and Fig. 3 are an enlarged plan view and an enlarged sectional view each illustrating part of the light diffusing film.

[0020]

This light diffusing film 10 comprises a light-transmitting resin sheet which contains a light diffusing agent and in which fine recesses 3 having the shape of an inverted regular quadrangular pyramid have been formed in order in one upper surface 2 serving as a light emission side. As shown in Fig. 1, this light diffusing film 10 is intended to be incorporated into a backlight unit of the edge light type so

that the light diffusing film 10 is disposed between a lightguide plate 20 and a lens film (prism film) 30 disposed over the lightguide plate 20. In Fig. 1, numeral 40 denotes a cold cathode fluorescent tube disposed along one side edge of the lightguide plate 20, and 50 denotes a light reflection sheet disposed under the lightguide plate 20. The light diffusing film 10 of the invention is useful especially as a light diffusing film for a backlight unit of the so-called edge light type in which light is emitted from the light source (cold cathode fluorescent tube) 40 disposed at an edge of the lightguide plate 20 as shown in Fig. 1.

[0021]

Preferably used as the light-transmitting resin constituting the light diffusing film 10 is a thermoplastic resin having a high total light transmittance, such as a polycarbonate, polyester, polyethylene, polypropylene, polyolefin copolymer (e.g., poly(4-methylpentene-1)), poly(vinyl chloride), cyclic polyolefin, acrylic resin, polystyrene, ionomer.

[0022]

Preferred of those resins are polycarbonates, polyesters (in particular, poly(ethylene terephthalate)), and cyclic polyolefins. This is because these resins have satisfactory heat resistance and are less apt to be deformed, rumpled, or otherwise adversely influenced by the heat generated

by, e.g., the cold cathode fluorescent tube after incorporation into a backlight unit.

[0023]

Polypropylene is preferred because it has the following and other advantages. This polymer has satisfactory crystallinity and transparency. As the degree of crystallinity thereof is increased, the modulus of elasticity improves. As a result, not only this polymer is less apt to thermally deform or rumple, but also the refractive index thereof increases. The increased refractive index results in a reduced difference in refractive index between the polymer and the light diffusing agent, and this increases the amount of light passing through the light diffusing film to heighten the luminance. In particular, polypropylene having a degree of crystallinity of 30-80% not only has high rigidity but has a refractive index of about 1.48-1.52, which is close to the refractive index (1.54) of a talc powder, which is advantageously used as a light diffusing agent. Because of this, even when a talc powder is incorporated, this polypropylene can give a light diffusing film which has a high total light transmittance and high luminance. The degree of crystallinity of polypropylene is more preferably 50-60%.

[0024]

The light diffusing agent is contained in the case where the light-transmitting resin used for the light diffusing film

has poor heat resistance or high thermal expansibility. Accordingly, in the case where the light-transmitting resin has satisfactory heat resistance and low thermal expansibility and does not arouse the trouble of rumpling of the light diffusing sheet, like polycarbonates, polyesters (in particular, poly(ethylene terephthalate)), and cyclic polyolefins, there is no particular need of incorporating a light diffusing agent. However, when it is necessary to improve the light diffusing functional to improve hiding properties, then it is preferred to add a light diffusing agent.

[0025]

As described above, the light diffusing agent to be incorporated in the light diffusing film 10 serves to diffuse light and thereby improve dot-hiding properties or the like, and further serves to inhibit the thermal expansion of the light diffusing film 10 and thereby prevent rumpling. As the light diffusing agent may be used any one of or a combination of two or more of particulate materials differing in refractive index from the light-transmitting resin constituting the light diffusing film 10, such as particulate inorganic materials, particulate metal oxides, and particulate organic polymers. As the particulate inorganic materials, use may be made of particles of glasses [A-glass (soda-lime glass), C-glass (borosilicate glass), and E-glass (low-alkali glass)], silica, mica, synthetic mica, calcium carbonate, magnesium carbonate,

barium sulfate, talc, montmorillonite, kaolin clay, bentonite, hectorite, and the like. As the particulate metal oxides may be used particles of titanium oxide, zinc oxide, alumina, and the like. As the particulate organic polymers may be used acrylic beads, styrene beads, particles of benzoguanamine, and the like. These light diffusing agents may have any shape, e.g., a spherical, platy, or fibrous shape.

[0026]

Of the light diffusing agents shown above, the particulate inorganic materials having a low coefficient of linear expansion are preferably used from the standpoint of inhibiting the thermal expansion of the light diffusing film 10. In particular, talc particles are optimal for the following reasons. Talc particles have an aspect ratio as large as 3-500 and reduce the coefficient of linear expansion of the light diffusing film 10. In addition, talc particles function as a nucleating agent for polypropylene and can thereby form evenly dispersed fine polypropylene crystallites while heightening the degree of crystallinity of the polypropylene. Thus, talc particles can heighten the modulus of elasticity and other mechanical strength of the light diffusing film 10 comprising polypropylene. On the other hand, glass particles are preferred for obtaining a light diffusing sheet having a high luminance because glass particles themselves are transparent and well transmit light.

[0027]

The light diffusing agent to be used has an average particle diameter of 0.1-100 μm, preferably 0.5-50 μm, more preferably 1-30 μm. In case where the particle diameter of a light diffusing agent is smaller than 0.1 μm, this light diffusing agent has poor dispersibility because it is apt to aggregate. Even when this light diffusing agent can be evenly dispersed, it has an impaired efficiency of light scattering because the wavelength of the light is longer than diameter of agent. Consequently, particles having a size of 0.5 μm or larger, especially 1 μm or larger, are preferred. On the other hand, in case where a light diffusing agent having a particle diameter larger than 100 μm is used, this results not only in uneven light scattering but in a reduced light transmittance and a trouble that particles are visually recognized. Consequently, particles of 50 μm or smaller, especially 30 μm or smaller, are preferred.

[0028]

The content of the light diffusing agent is not particularly limited. However, it is preferably 35% by mass or lower. In case where the content thereof is higher than 35% by mass, the light transmittance and luminance of the light diffusing film decrease due to the light scattering, reflection, and absorption caused by the light diffusing agent. Because of this, even when a backlight unit having such a light diffusing

film incorporated therein is used to illuminate a display from the back side, images on the display screen are difficult to recognize. The content of the agent is preferably 15-35% by mass, especially preferably 18-30% by mass.

[0029]

The thickness t of the light diffusing film 10 is not particularly limited. However, in the case where the light diffusing film 10 is to be incorporated into a backlight unit, the thickness thereof is preferably about 50-300 μm. In case where the light diffusing sheet is thinner than 50 μm, this light diffusing film has a reduced modulus of elasticity and is apt to rumple. This light diffusing film further shows reduced light diffusion and hence has insufficient dot-hiding properties. In addition, in this light diffusing film, the recesses 3 formed in the upper surface 2 serving as a light emission side are inevitably too fine and, hence, the function of reducing the brightness peak angle of the diffused light emitted from the upper surface (light emission side) 2 becomes insufficient. On the other hand, in case where the light diffusing film is thicker than 300 μm, this tends to result in a reduced light transmittance and reduced luminance. There is hence a possibility that images on the display might be difficult to recognize. The thickness of the light diffusing film 10 is more preferably 80-200 μm, even more preferably 100-150 μm.

[0030]

A major feature of this light diffusing sheet 10 resides in that fine recesses 3 having the shape of an inverted regular quadrangular pyramid, which is a kind of inverted polyangular pyramid, have been formed in a lengthwise/crosswise arrangement in one upper surface 2 serving as a light emission side. These recesses 3 serve to reduce the brightness peak angle of the diffused light emitted from the upper surface (light emission side) 2 of the light diffusing sheet 10. The light diffusing sheet 10 thus enables the diffused light to be easily brought to the front direction (the direction perpendicular to the screen of the liquid-crystal display) by the lens film 30 and thereby heightens the luminance of the liquid-crystal display screen or the like.

Meanwhile, the lower surface serving as a light entrance side may be formed with recesses that are the same as the recesses having the shape of an inverted polyangular pyramid, may be formed with recesses and protrusions (matte), or may be formed as a flat surface.

[0031]

The shape of the recesses 3 is not limited to the shape of an inverted regular quadrangular pyramid as in this embodiment. It is, however, necessary that the shape thereof should be any of the shape of an inverted polyangular pyramid, the shape of an inverted truncated polyangular pyramid, the shape of

an inverted cone, and the shape of an inverted truncated cone. The shape of an inverted truncated polyangular pyramid means the shape formed by horizontally cutting off a top part, i.e., a lower part, from an inverted polyangular pyramid; while the shape of an inverted truncated cone means the shape formed by horizontally cutting off a top part, i.e., a lower part, from an inverted cone. It should, however, be noted that the surface formed by truncating may be a concave surface. Consequently, in the case of, e.g., recesses having the shape of an inverted truncated cone, examples thereof include recesses which as a whole are nearly semispherical.

[0032]

Recesses of the shape of an inverted polyangular pyramid and recesses of the shape of an inverted cone are preferred because the inclined faces or tapered surfaces of these recesses can be made to have a large area and hence have the enhanced function of refracting light to thereby reduce the brightness peak angle. In particular, recesses 3 having the shape of an inverted regular quadrangular pyramid as in this embodiment are exceedingly preferred because they have the following advantages: such recesses 3 can be continuously formed either in the lengthwise/crosswise directions or in an oblique-line arrangement as will be described later and, hence, the proportion of the area occupied by the recesses 3 in an upper surface 2 can be increased to 100% at the most; and these recesses

3 are remarkably effective in reducing the brightness peak angle of the diffused light emitted from the upper surface (light emission side) 2. Furthermore, recesses 3 having the shape of an inverted truncated quadrangular pyramid (in other words, the recesses 3 having the shape of an inverted quadrangular prismoid) such as those shown in Fig. 4 and recesses having the shape of an inverted truncated cone are preferred because of an advantage that such recesses can be extremely easily formed by embossing. In the case where the recesses 3 have the shape of an inverted polyangular pyramid or inverted cone, it is preferred from the standpoint of production that the deepest parts of the recesses be rounded appropriately.

[0033]

The bevel θ between the upper surface 2 and each inclined face 4 of fine recess 3 having an inverted regular quadrangular pyramid shape is preferably 15-70°. As long as that bevel is within this range, the brightness peak angle of the diffused light emitted from the upper surface 2 serving as a light emission side can be reduced to about 25-45° by the light-refracting function of the inclined faces 4. The bevel θ of the inclined faces 4 of the recesses 3 is more preferably 20-50°. In particular, the light diffusing film 10 in which recesses 3 having the shape of an inverted regular quadrangular pyramid with inclined faces 4 having a bevel of 25° or 45° have been formed in the upper surface 2 (light emission side)

exhibits the satisfactory effect of reducing the brightness peak angle as supported by the experimental results which will be given later.

[0034]

For the same reason, also in the case of recesses having the shape of an inverted polyangular pyramid other than inverted regular quadrangular pyramids or the shape of an inverted truncated polyangular pyramid or in the case of recesses having the shape of an inverted cone or inverted truncated cone, the bevel of the inclined faces of the former recesses or the bevel of the ridgelines of the latter recesses is regulated preferably to 15-70°, more preferably 20-50°.

[0035]

In this embodiment of the light diffusing film 10, recesses 3 having the shape of an inverted regular quadrangular pyramid have been continuously formed in a lengthwise/crosswise arrangement as shown in Fig. 2, whereby the proportion of the area occupied by the recesses 3 in the upper surface 2 has been regulated to 100%. However, recesses 3 may be formed in an upper surface 2 in a lengthwise/crosswise arrangement so as to be spaced from one another as shown in, e.g., Fig. 7 to thereby regulate the proportion of the area occupied by these recesses 3 to a value of 30% or higher and lower than 100%. In case where the proportion of the recesses 3 is smaller than 30%, the proportion of the flat surface, which makes

substantially no contribution to the reduction of brightness peak angle, is too large and the function of reducing the brightness peak angle decreases. Especially when the proportion of the area occupied by the recesses is 90-100% and the bevel of the inclined faces of the recesses 3 is 20-50° as stated above, the function of reducing the brightness peak angle is remarkable. In the case where the proportion of the area occupied by the recesses 3 is 100% or smaller, it is preferred to finely roughen the flat surface (upon surface between the recesses), which is the surface not occupied by the recesses, to cause the finely roughened surface to scatter light.

[0036]

The depth d of the deepest parts of the recesses 3 is preferably from 3/10 to 9/10 the thickness t of the light diffusing film. When the deepest parts have such a depth, the light diffusing film 10 does not have a considerably reduced tear strength and the recesses 3 have a moderate size (fineness). This light diffusing film 10 hence has the sufficient function of reducing the brightness peak angle.

[0037]

In this embodiment, the length a of each side of each fine recess 3 having the shape of an inverted regular quadrangular pyramid varies depending on the depth d of the deepest part of the recess 3 and the bevel θ. However, the

side length a is preferably about 100-600 μm from the standpoint of the function of reducing the brightness peak angle. In case where the length a of each side is shorter than 100 μm, the recesses 3 are so fine that the function of randomly diffusing light becomes stronger than the function of reducing the brightness peak angle. Conversely, in case where the length a is longer than 600 μm, the recesses 3 are so rough that it is difficult to stably impart the bevel θ to the upper surface of the film.

[0038]

The recesses 3 having an inverted polyangular shape may be formed in a lengthwise/crosswise arrangement as in this embodiment, or may be formed in an oblique-line arrangement as shown in Fig. 8. When the recesses 3 are formed in a lengthwise/crosswise arrangement, there are cases where a moiré or interference fringe generates. In contrast, when the recesses 3 have been formed in an oblique-line arrangement, such a moiré or interference fringe is less visible and luminance unevenness does not result.

[0039]

In this embodiment of the light diffusing film 10, the lower surface 5 serving as a light entrance side is a flat surface. In some cases, however, recesses and protrusions (matte surface) which have the arithmetic mean deviation of the profile of 10 μm or less may be formed on the lower surface

5. The formation of such microfine recesses and protrusions on the lower surface 5 has an advantage that these recesses and protrusions further enhance light diffusion to further improve dot-hiding properties. Furthermore, recesses which are the same as the recesses 5 having the shape of an inverted polyangular pyramid formed in the upper surface 2 may be formed in the lower surface 5.

[0040]

The light diffusing film 10 of Example 1, which has the constitution described above, can be efficiently and continuously produced, for example, by the following method. First, a light-transmitting resin containing the light diffusing agent described above is heated/melted and continuously extruded into a film form through the extrusion orifice of an extruder. Subsequently, this film formed by extrusion molding is continuously passed through the nip between an embossing roll (a roll having, formed in order on the surface thereof, fine projections which correspond and conform to the recesses 3) and a support roll to form the recesses 3 in a lengthwise/crosswise arrangement in one of the surfaces of the film with the embossing roll and thereby continuously form a light diffusing film 10. The light diffusing film 10 of Example 1 can be thus produced efficiently and continuously by forming recesses 3 with an embossing roll while conducting continuous extrusion molding. Consequently, this light

diffusing film 10 has far higher productivity than the light diffusing sheets produced by the bead coating method heretofore in use or light diffusing sheets which must be produced one by one by injection molding, hot-press molding, or the like, such as the light diffusing sheet disclosed in patent document 1. A cost reduction can hence be attained, and a light diffusing film as thin as, e.g., 150 μm or thinner can also be easily produced.

[0041]

This light diffusing film 10 of Example 1 is incorporated into a backlight unit of the edge light type so that it is disposed between the lightguide plate 20 and the lens film 30 and that the upper surface 2 having recesses 3 formed therein serves as a light emission side, as shown in Fig. 1. When this backlight unit is used, the light having a large brightness peak angle (usually, light having a brightness peak angle of 60° or larger) which was emitted by the light source (cold cathode fluorescent tube) 40 and has entered the light diffusing film 10 through the lightguide plate 20 is sufficiently diffused by the light diffusing agent contained in the light diffusing film 10. This diffused light is brought to a direction where the brightness peak angle becomes small by the light-refracting function of the inclined faces 4 of the recesses 3 having the shape of an inverted regular quadrangular pyramid. The diffused light is thus converted to diffused light having a small

brightness peak angle (diffused light having a brightness peak angle of about 25-45°) and led to the lens film 30. Consequently, this diffused light having a small brightness peak angle is brought to the front direction (the direction perpendicular to the screen of the liquid-crystal display) by the lens film 30. The luminance of the liquid-crystal display screen or the like can hence be sufficiently heightened. In addition, dot-hiding properties are improved and the generation of a moiré or interference fringe is inhibited, because light is intensely diffused by the light diffusing agent contained in the light diffusing film 10.

[EXAMPLE 2]

[0042]

Fig. 4 is an outline sectional view illustrating part of a light diffusing film according to another embodiment of the invention.

[0043]

This light diffusing film 11 comprises a light-transmitting resin film which contains no light diffusing agent and in which fine recesses 3 having the shape of an inverted truncated regular quadrangular pyramid have been formed apart from one another in a lengthwise/crosswise arrangement in the upper surface 2 serving as a light emission side.

[0044]

The light-transmitting resin to be used in this embodiment can be any of the aforementioned light-transmitting resins having a high total light transmittance. However, it is especially preferred to select a resin which has high heat resistance even when no light diffusing agent is contained therein and which is free from troubles such as rumpling after incorporation in a backlight unit. As such resins, polycarbonates, polyesters (in particular, biaxially stretched poly(ethylene terephthalate)), and cyclic polyolefins are desirable.

[0045]

As stated above, the fine recesses 3 in this embodiment have the shape of an inverted truncated regular quadrangular pyramid, in other words, the shape of an inverted regular quadrangular prismoid, which is a kind of inverted truncated polyangular pyramid. Namely, the upper-end opening of each of these recesses 3 is a square and the bottom of the recess 3 also is a square, which is smaller than the upper-end opening. The recess 3 has the shape of an inverted regular quadrangular prismoid. The bevel θ of each inclined face 4 is 15-70° as in Example 1. The areal proportion of the recess 3 to the upper surface 2, the depth d of the deepest part and the length a of each side thereof are the same as those in Example 1. The areal proportion is 30-100%. The depth d is about from

3/10 to 9/10 the thickness of the light diffusing film 11. The length of the side a is about 10-600 μm. The thickness of the light diffusing film 11 is 50-300 μm as in Example 1. These recesses 3 may be formed in a lengthwise/crosswise arrangement or may be formed in an oblique-line arrangement. Furthermore, the recesses 3 or fine recesses and protrusions may be formed on the lower surface 5, in which recesses 3 have not been formed and which serves as a light entrance side.

[0046]

When the light diffusing film 11 of this embodiment is incorporated into a backlight unit of the edge light type so that the upper surface 2 having recesses 3 thereof formed in order therein serves as a light emission side like the light diffusing film 10 described above and this backlight unit is used, then the following effect is brought about. The light having a large brightness peak angle which was emitted by the light source (cold cathode fluorescent tube) and has entered the light diffusing film 11 through the lightguide plate is brought to a direction where the brightness peak angle becomes small by the light-refracting function of the inclined faces 4 of the recesses 3 having the shape of an inverted truncated regular quadrangular pyramid (an inverted regular quadrangular prismoid). The diffused light is thus converted to diffused light having a small brightness peak angle and led to the lens film. The luminance of the screen of a liquid-crystal display

or the like can hence be heightened.

EXAMPLE 3

[0047]

Fig. 5 is an outline sectional view illustrating part of a light diffusing sheet according to still another embodiment of the invention.

[0048]

This light diffusing film 12 comprises a core layer 1 (light diffusing sheet main body) made of a light-transmitting resin containing a light diffusing agent and surface layers 6 and 6 which are made of a light-transmitting resin and have been laminated respectively to both sides of the core layer 1. The upper surface layer 6 serving as a light emission side has recesses 3 having the shape of an inverted regular quadrangular pyramid described above continuously formed in a lengthwise/crosswise arrangement in the surface 2 of the layer 6. The lower surface layer 6 serving as a light entrance side has, on the surface, fine recesses and protrusions 7 having the arithmetic mean deviation of the profile of 10 μm or lower.

[0049]

Although the core layer 1 in this embodiment contains a light diffusing agent, the layer 1 need not contain the agent. Furthermore, in this embodiment, surface layers 6 and 6 have been formed respectively on the upper and lower sides of the

core layer 1 and the upper surface layer 6 only has recesses 3 formed in the surface 2 thereof. However, recesses 3 may be likewise formed also in the surface of the lower surface layer 6. In some cases, a constitution may be employed in which a surface layer 6 is formed on only one of the upper and lower surfaces of the core layer 1 and recesses 3 are formed only in the surface of this surface layer 6. It is a matter of course that recesses and protrusions 7 as shown in Fig. 5 may be formed on that surface of the surface layer 6 in which fine recesses have not been formed and on the surface of the core layer 1. These recesses and protrusions 7 may, of course, be omitted so that the surface remains flat.

[0050]

The surface layers 6 and 6 are layers which are made of the same light-transmitting resin as the light-transmitting resin described above and contain no light diffusing agent. The surface layers 6 and 6 are formed for the purpose of covering the light diffusing agent exposed on both sides of the core layer 1 made of a light-transmitting resin. Because of this, a thickness as small as about 5-20 μm suffices for the surface layers 6 and 6.

[0051]

The recesses 3 and other constitutions of this light diffusing film 12 are the same as in the light diffusing film 10 described above. Explanations thereon are hence omitted.

[0052]

The light diffusing film 12 of Example 3 described above can be efficiently and continuously produced, for example, by the following method. First, using a multilayer coextrusion molding machine, a molten-state light-transmitting resin containing the light diffusing agent described above and a molten-state light-transmitting resin containing no light diffusing agent are subjected to three-layer coextrusion molding so that the latter resin is superposed on the upper and lower sides of the former resin. Thus, a film having a three-layer structure is continuously formed, which is composed of a core layer 1 made of the light-transmitting resin containing the light diffusing agent and surface layers 6 and 6 containing no light diffusing agent and laminated respectively to both sides of the core layer 1. Subsequently, this sheet of a three-layer structure formed by extrusion molding is continuously passed through the nip between upper and lower embossing rolls (an upper roll having, formed in order on the surface thereof, fine projections corresponding and conforming to the recesses 3 and a lower roll having, formed on the surface thereof, microfine recesses and protrusions corresponding and conforming to the microfine recesses and protrusions 7). Thus, the recesses 3 in a lengthwise/crosswise arrangement and the microfine recesses and protrusions 7 are formed respectively on one side and the opposite side of the sheet with these

embossing rolls to thereby continuously produce a light diffusing film 12. The light diffusing film 12 of Example 3 can be thus produced efficiently and continuously by forming recesses 3 and microfine recesses and protrusions 7 with upper and lower embossing rolls while conducting continuous extrusion molding. In addition, this operation for producing the sheet of a three-layer structure by three-layer coextrusion molding has an advantage that since the light diffusing agent contained in the interlayer light-transmitting resin is covered by the light-transmitting resin for forming the upper and lower surface layers, the molding operation is free from the so-called eye mucus phenomenon in which the light diffusing agent adheres to the periphery of the extrusion orifice of the extrusion molding machine and, hence, the sheet surfaces can be prevented from bearing streak lines.

[0053]

This light diffusing film 12 of Example 3 is incorporated into a backlight unit of the edge light type so that it is disposed between the lightguide plate 20 and the lens film 30. When this backlight unit is used, the following effect is brought about besides the same effect as that obtained with the light diffusing film 10 described above. Namely, due to the microfine recesses and protrusions 7 formed on a light entrance side, light diffusion is enhanced and the hiding properties are further improved.

EXAMPLE 4

[0054]

Fig. 6 is an outline sectional view illustrating part of a light diffusing sheet according to a further embodiment of the invention.

[0055]

This light diffusing film 13 comprises a core layer 1 (light diffusing sheet main body) made of a light-transmitting resin containing a light diffusing agent and surface layers 8 and 8 which are made of a light-transmitting resin containing a light diffusing agent and have been laminated respectively to both sides of the core layer 1. The upper surface layer 8 serving as a light emission side has the fine recesses 3 continuously formed in a lengthwise/crosswise arrangement in the surface 2 of the layer 8. The lower surface layer 8 serving as a light entrance side has surface recesses and protrusions 7 which have the arithmetic mean deviation of the profile of 10 μm or lower.

[0056]

Although the core layer 1 in this embodiment contains a light diffusing agent, the layer 1 does not need to contain the agent. Furthermore, in this embodiment, surface layers 8 and 8 have been formed respectively on the upper and lower sides of the core layer 1 and the upper surface layer 8 only has recesses 3 formed in the surface 2 thereof. However,

recesses 3 may be formed also in the surface of the lower surface layer 8. In some cases, a constitution may be employed in which a surface layer 8 is formed on only one of the upper and lower surfaces of the core layer 1 and recesses 3 are formed in the surface of this surface layer 8. Fine recesses and protrusions 7, such as those shown in Fig. 6, may be formed on that surface of the surface layer 8 in which recesses have not been formed and on the surface of the core layer. These recesses and protrusions 7 may be omitted.

[0057]

The surface layers 8 and 8 are layers made of the light-transmitting resin described above which contains the light diffusing agent described above. Since the light diffusing agent contained in the surface layers 8 also serve to diffuse light, this light diffusing film 13 can have further improved light diffusing performance. In addition, the surface layers 8 have a reduced coefficient of linear expansion due to the light diffusing agent like the core layer 1 and, hence, the light diffusing sheet 13 can be prevented from rumpling. The amount of the light diffusing agent to be contained in these surface layers 8 is desirably regulated to 10-40% by weight. In the case where this light diffusing agent is the same as the light diffusing agent for the core layer 1, it is necessary that the light diffusing agent should be contained in different amounts. When different light

diffusing agents are used, they may be contained in the same amount.

[0058]

Preferred light diffusing agents to be contained in the surface layers 8 are the particulate organic polymers and particulate glasses shown above. The reasons for this are as follows. The particulate organic polymers have a smooth particle surface and do not mar the lens film even when protrude from the surface layer 8. In addition, the particulate organic polymers are less apt to cause the eye mucus phenomenon during extrusion molding. On the other hand, the particulate glasses have a high total light transmittance and, hence, the incorporation thereof reduces the coefficient of linear expansion without lowering the total light transmittance of the light diffusing sheet.

[0059]

The recesses 3 and other constitutions of this light diffusing film 13 are the same as in the light diffusing film 10 described above. Explanations thereon are hence omitted.

[0060]

The light diffusing film 13 of Example 4 described above also can be efficiently and continuously produced in the same manner as for the light diffusing film 12, except that a light-transmitting resin containing a light diffusing agent is used as the resin for forming the surface layers 8. Details

thereof are hence omitted.

[0061]

The light diffusing film 13 of Example 4 is incorporated into a backlight unit of the edge light type so that it is disposed between the lightguide plate 20 and the lens film 30. When this backlight unit is used, the following effects are brought about besides the same effects as those obtained with the light diffusing film 12 described above. Namely, the function of diffusing light is enhanced by the surface layers 8, and the light diffusing film 13 satisfactory diffuses light and has improved dot-hiding properties. In addition, since the surface layers 8 also have a reduced coefficient of linear expansion, the light diffusing film 13 does not rumple even upon exposure to the heat of, e.g., the light source in the backlight unit and can attain an even luminance.

[0062]

Next, Experimental Examples for the invention and Comparative Examples will be explained.

[0063]

[EXPERIMENTAL EXAMPLE 1]

Using a three-layer coextrusion molding machine, molten-state polypropylene evenly containing 21% by mass talc particles having an average particle diameter of 7.2 μm as a light diffusing agent was extruded into a film form having

a thickness of 108 μm and, simultaneously therewith, polypropylene containing 30% by mass A-glass light diffusing agent was coextruded and superposed in a thickness of 11 μm on each of the upper and lower sides of that extrudate. Thus, a light-transmitting laminated film of a three-layer structure having an overall thickness of 130 μm was continuously molded. This laminated film was passed through the nip between an embossing roll having innumerable fine projections which had the shape of a regular quadrangular pyramid and had been continuously formed in order on the roll surface along the circumferential direction and axial direction and a support roll having a smooth surface. Thus, a light diffusing film was obtained in which one upper surface thereof serving as a light emission side had fine recesses having the shape of an inverted regular quadrangular pyramid (depth of deepest part, about 95 μm; bevel of inclined faces, about 25°; length of each side, about 400 μm) continuously formed therein in a lengthwise/crosswise arrangement and the other lower surface thereof serving as a light entrance side was flat (proportion of the area occupied by the recesses, 100%).

[0064]

This light diffusing film was measured for total light transmittance and haze with hazeometer NDH 2000 [manufactured by Nippon Denshoku Industries Co., Ltd.]. As a result, the total light transmittance and haze thereof were found to be

89.7% and 90.9%, respectively, as shown in Table 1 given later.

[0065]

Subsequently, the light diffusing film was placed on the lightguide plate of a backlight unit for liquid-crystal displays, and the light source was switched on. A luminance meter [BM-7, manufactured by Topcon Corp.] was disposed at a distance of 35 cm from the light diffusing sheet to measure the luminance. As a result, the luminance was found to be 1,854 cd/m^2 as shown in Table 1.

[0066]

Furthermore, the luminance was measured while varying the angle by inclining the backlight unit upward and downward in such a manner that the light source revolved from the upper to the lower side. The results obtained are shown in Fig. 9. Moreover, the luminance was measured while varying the angle by inclining the backlight unit leftward and rightward, and the results obtained are shown in Fig. 10.

[0067]

In the luminance measurements, whether the dots on the back side of the lightguide plate were hidden or not was visually examined. As a result, the dots were completely hidden and were unable to be visually recognized. The dot-hiding properties were satisfactory. The backlight unit was further visually examined for rumpling. As a result, no rumples were observed. The results of these examinations also are shown

in Table 1.

[0068]

Incidentally, a moiré was slightly observed when the light diffusing film of Experimental Example 1 was used. However, when a light diffusing film prepared by obliquely cutting that light diffusing film at an angle of 45° (a light diffusing film in which recesses having the shape of an inverted regular quadrangular pyramid had been continuously formed in an oblique-line arrangement) was placed on the lightguide plate of a backlight unit in the same manner as described above, then no moiré was observed at all.

[0069]

[EXPERIMENTAL EXAMPLE 2]

A light diffusing film (proportion of the area occupied by recesses, 100%) was obtained in the same manner as in Experimental Example 1, except that recesses having the shape of an inverted regular quadrangular pyramid having a depth of the deepest part of about 85 μm, bevel of the inclined faces of about 45°, and length of each side of about 200 μm were continuously formed in a lengthwise/crosswise arrangement in the upper surface serving as a light emission side by replacing the embossing roll with another one.

[0070]

This light diffusing film was measured for total light transmittance, haze, and luminance in the same manners as in

Experimental Example 1. The results obtained are shown in Table 1 given later. A backlight unit having the light diffusing film incorporated therein was measured for luminance while varying the angle by inclining the unit upward and downward and by inclinig it leftward and rightward, in the same manner as in Experimental Example 1. The results of these measurements are shown in Fig. 9 and Fig. 10, respectively. Furthermore, the backlight unit was visually examined as to whether the dot-hiding properties were satisfactory and whether rumples were observed, in the same manners as in Experimental Example 1. The results thereof are shown in Table 1 given later.

[0071]

[EXPERIMENTAL EXAMPLE 3]

A light diffusing film was obtained in the same manner as in Experimental Example 1, except that an embossing roll in which innumerable fine projections of a nearly semispherical shape had been continuously formed in order on the roll surface along the circumferential direction and axial direction was used in place of the embossing roll used in Experimental Example 1. The light diffusing film thus obtained had innumerable recesses having a nearly semispherical shape (the shape of an inverted truncated cone in which the cut surface was concave and which was nearly semispherical; diameter, about 2-15 μm) formed in random order in the upper surface thereof serving

as a light emission side.

[0072]

This light diffusing film was measured for total light transmittance, haze, and luminance in the same manners as in Experimental Example 1. The results obtained are shown in Table 1 given later. A backlight unit having the light diffusing film incorporated therein was measured for luminance while varying the angle by inclining the unit upward and downward and by inclinig it leftward and rightward, in the same manner as in Experimental Example 1. The results of these measurements are shown in Fig. 9 and Fig. 10, respectively. Furthermore, the backlight unit was visually examined as to whether the dot-hiding properties were satisfactory and whether rumples were observed, in the same manners as in Experimental Example 1. The results thereof are shown in Table 1 given later.

[0073]

[COMPARATIVE EXAMPLE 1]

A light diffusing film having microfine recesses and protrusions formed in random order on the upper surface thereof serving as a light emission side was produced in the same manner as in Experimental Example 1, except that a matte roll having microfine recesses and protrusions on the surface thereof was used in place of the embossing roll used in Experimental Example 1.

[0074]

This light diffusing film was measured for total light transmittance, haze, and luminance in the same manners as in Experimental Example 1. The results obtained are shown in Table 1 given later. A backlight unit having the light diffusing film incorporated therein was measured for luminance while varying the angle by inclining the unit upward and downward and by inclinig it leftward and rightward, in the same manner as in Experimental Example 1. The results of these measurements are shown in Fig. 9 and Fig. 10, respectively. Furthermore, the backlight unit was visually examined as to whether the dot-hiding properties were satisfactory and whether rumples were observed, in the same manners as in Experimental Example 1. The results thereof are shown in Table 1 given later.

[0075]

[COMPARATIVE EXAMPLE 2]

A light diffusing film having innumerable fine projections having a nearly semispherical shape formed on the upper surface thereof serving as a light emission side was obtained in the same manner as in Experimental Example 1, except that an embossing roll having innumerable fine semispherical recesses in the surface thereof was used in place of the embossing roll used in Experimental Example 1.

[0076]

This light diffusing film was measured for total light

transmittance, haze, and luminance in the same manners as in Experimental Example 1. The results obtained are shown in Table 1 given below. A backlight unit having the light diffusing film incorporated therein was measured for luminance while varying the angle by inclining the unit upward and downward and by inclinig it leftward and rightward, in the same manner as in Experimental Example 1. The results of these measurements are shown in Fig. 9 and Fig. 10, respectively. Furthermore, the backlight unit was visually examined as to whether the dot-hiding properties were satisfactory and whether rumples were observed, in the same manners as in Experimental Example 1. The results thereof are shown in Table 1 given below.

[0077]

A backlight unit having no light diffusing sheet was also measured for luminance while varying the angle by inclining the unit leftward and rightward. The results thereof are shown in Fig. 10.

[0078]

[Table 1]

		Experimental Example 1	Experimental Example 2	Experimental Example 3	Comparative Example 1	Comparative Example 2
One upper surface (light emission side)		recesses of inverted regular quadrangular pyramid shape (bevel, 25°)	recesses of inverted regular quadrangular pyramid shape (bevel, 45°)	recesses of nearly semispherical shape	microfine recesses and protrusions	projections of nearly semispherical shape
Other lower surface (light entrance side)		flat	flat	flat	flat	flat
Total light transmittance	%	89.7	71.2	87.9	89.9	90.5
Haze	%	90.9	90.7	87.2	87.5	90.0
Luminance	cd/m^2	1854	1885	1834	1815	1817
Dot-hiding property		○	○	○	○	○
Rumpling		none	none	none	none	none

[0079]

The following can be seen from Table 1. The light diffusing films of Experimental Examples 1, 2, and 3 according to the invention and the light diffusing films of Comparative Examples 1 and 2, which contain a light diffusing agent, each have a haze of 87% or higher, which is satisfactory. There is almost no difference in haze between the light diffusing films of the Experimental Examples and the light diffusing films of the Comparative Examples. It can hence be seen that there is no difference in dot-hiding properties between these. However, the luminances in Experimental Examples 1, 2, and 3 are as high as 1,834 cd/m^2 or above, whereas the luminances in Comparative Examples 1 and 2 are as low as 1,817 cd/m^2 or below. It can be seen that the light diffusing films having recesses having the shape of an inverted regular quadrangular pyramid or a nearly semispherical shape have a better luminance than the light diffusing film having microfine recesses and protrusions and the light diffusing film having semispherical projections. In particular, the light diffusing films of Experimental Examples 1 and 2, which have recesses having the shape of an inverted regular quadrangular pyramid, have a luminance higher by as large as 70-37 cd/m^2 than those in Comparative Examples 1 and 2 and by as large as 51-20 cd/m^2 than that of the light diffusing film of Experimental Example 3, which has nearly semispherical recesses. The light

diffusing films of Experimental Examples 1 and 2 are found to have excellent condensing ability.

[0080]

Fig. 10 shows that in the range of from 45° right to 45° left, the luminances of the light diffusing films of Experimental Examples 1 and 2, which have recesses having the shape of an inverted regular quadrangular pyramid and formed in a lengthwise/crosswise arrangement, are higher than the luminances of the light diffusing film of Experimental Example 3, which has nearly semispherical recesses, the light diffusing film of Comparative Example 1, which has microfine recesses and protrusions formed randomly, and the light diffusing film of Comparative Example 2, which has semispherical projections. It can be seen from these results that in the range of from 45° right to 45° left, the light diffusing films of Experimental Examples 1 and 2, in which recesses having the shape of an inverted regular quadrangular pyramid have been formed in order, are superior in the property of condensing diffused light to the light diffusing film of Experimental Example 3 or the light diffusing films of Comparative Examples 1 and 2.

[0081]

The following can be further seen from Fig. 10. The lightguide plate alone having no light diffusing film superposed thereon has a brightness peak at each of around

60° right and around 60° left. In contrast, the light diffusing films of Comparative Examples 1 and 2 and Experimental Example 3 each have a brightness peak at each of around 30°-40° right and around 30°-40° left. Furthermore, the light diffusing films of Experimental Examples 1 and 2, in which recesses having the shape of an inverted regular quadrangular pyramid have been formed in order, each have a brightness peak at each of around 30° right and around 30° left. On the other hand, Fig. 9 shows that the light diffusing films of Comparative Examples 1 and 2 each have a brightness peak at around 50° (lower side of the light source), while the light diffusing films of Experimental Examples 1, 2, and 3 each have a brightness peak at around 40° (lower side of the light source).

[0082]

From those results, the following can be seen. The light diffusing films of Experimental Examples 1, 2, and 3 and Comparative Examples 1 and 2 each have the effect of reducing the brightness peak angle. However, the light diffusing films of Experimental Examples 1, 2, and 3, in which recesses having the shape of an inverted regular quadrangular pyramid or a semispherical shape (the shape of an inverted truncated cone in which the cut surface is concave) have been formed in order, are more effective in reducing the brightness peak angle than the light diffusing films of Comparative Examples 1 and 2, in which projections or random recesses and protrusions have

been formed. In Experimental Examples 1, 2, and 3, the light is further brought to the front direction (the direction perpendicular to the screen of the liquid-crystal display) by the lens film to improve the brightness as measured from the central direction in front of the liquid-crystal display screen. In particular, Experimental Examples 1 and 2, in which recesses having the shape of an inverted regular quadrangular pyramid have been formed in order, are effective in further reducing the brightness peak angle as compared with Experimental Example 3, in which nearly semispherical recesses have been formed in order, and thereby improving the brightness as measured from the central front direction.

[0083]

Furthermore, as Table 1 shows, the light diffusing sheets of Experimental Examples 1, 2, and 3 and Comparative Examples 1 and 2, which each contain a light diffusing agent, each have a haze as high as 87% or above and show satisfactory dot-hiding properties. No rumples are observed therein.

[0084]

[EXPERIMENTAL EXAMPLE 4]

Using a single-layer extrusion molding machine, molten-state polypropylene was extruded into a sheet form having a thickness of 145 μm. This sheet was passed through the nip between an embossing roll having innumerable fine projections which had the shape of a truncated regular quadrangular pyramid

(regular quadrangular prismoid) and had been continuously formed in order on the roll surface along the circumferential direction and axial direction and a support roll whose surface had been finely embossed. Thus, a light diffusing film was obtained in which one upper surface thereof serving as a light emission side had recesses having the shape of an inverted truncated regular quadrangular pyramid (inverted regular quadrangular prismoid) (depth of deepest part, about 85 μm; bevel of inclined faces, about 45°; length of long side in the upper part × length of short side, about 200 × 200 μm; space between recesses, 10 μm) continuously formed therein in a lengthwise/crosswise arrangement and the other lower surface had microfine recesses and protrusions (proportion of the area occupied by the recesses, 92%).

[0085]

This light diffusing film was measured for total light transmittance and haze in the same manners as in Experimental Example 1. The results obtained are shown in Table 2 given later. A backlight unit having the light diffusing film incorporated therein was measured for luminance while varying the angle by inclining the unit upward and downward and by inclinig it leftward and rightward, in the same manner as in Experimental Example 1. The results of these measurements are shown in Fig. 11 and Fig. 12, respectively. Furthermore, the backlight unit was visually examined as to whether the

dot-hiding properties were satisfactory and whether rumples were observed, in the same manners as in Experimental Example 1. The results thereof are shown in Table 2 given later. The arithmetic mean deviation of the profile of the microfine recesses and protrusions on the lower surface of this light diffusing film was determined with DEKTAK IIA, manufactured by ULVAC Corp., in accordance with JIS B 0601. The results thereof are also shown in Table 2.

[0086]

[EXPERIMENTAL EXAMPLE 5]

A light diffusing film in which the same recesses as in Experimental Example 4, which had the shape of an inverted truncated regular quadrangular pyramid, had been formed in order in the upper surface thereof was obtained in the same manner as in Experimental Example 4, except that the support roll was replaced by a roll having a smooth surface to thereby make the lower surface serving as a light entrance side flat.

[0087]

This light diffusing film was measured for total light transmittance, haze, dot-hiding properties, rumpling, and arithmetic mean deviation of the profile in the same manners as in Experimental Example 1. The results obtained are shown in Table 2 given later. Furthermore, a backlight unit having the light diffusing film incorporated therein was measured for luminance while varying the angle by inclining the unit

upward and downward and by inclinig it leftward and rightward, in the same manner as in Experimental Example 1. The results of these measurements are shown in Fig. 11 and Fig. 12, respectively.

[0088]

[EXPERIMENTAL EXAMPLE 6]

A light diffusing film was obtained in the same manner as in Experimental Example 4, except that recesses having the shape of an inverted regular quadrangular pyramid (depth of deepest part, about 95 μm; bevel of inclined faces, about 25°; length of long side in the upper part × length of short side, about 380 × 380 μm; space between recesses, 20 μm) were continuously formed in a lengthwise/crosswise arrangement in the upper surface serving as a light emission side by replacing the embossing roll with another one.

[0089]

This light diffusing film was measured for total light transmittance, haze, dot-hiding properties, rumpling, and arithmetic mean deviation of the profile in the same manners as in Experimental Example 1. The results obtained are shown in Table 2 given later. Furthermore, a backlight unit having the light diffusing film incorporated therein was measured for luminance while varying the angle by inclining the unit upward and downward and by inclinig it leftward and rightward, in the same manner as in Experimental Example 1. The results

of these measurements are shown in Fig. 11 and Fig. 12, respectively.

[0090]

[COMPARATIVE EXAMPLE 3]

A light diffusing film having microfine recesses and protrusions formed on the upper surface thereof serving as a light emission side and on the lower surface thereof serving as a light entrance side was obtained in the same manner as in Experimental Example 4, except that the embossing roll was replaced by a roll having microfine recesses and protrusions.

[0091]

This light diffusing film was measured for total light transmittance, haze, dot-hiding properties, rumpling, and arithmetic mean deviation of the profile in the same manners as in Experimental Example 1. The results obtained are shown in Table 2 given below. Furthermore, a backlight unit having the light diffusing film incorporated therein was measured for luminance while varying the angle by inclining the unit upward and downward and by inclinig it leftward and rightward, in the same manner as in Experimental Example 1. The results of these measurements are shown in Fig. 11 and Fig. 12, respectively.

[0092]

[Table 2]

		Experimental Example 4	Experimental Example 5	Experimental Example 6	Comparative Example 3
One surface (light emission side)		recesses of inverted rectangular prismoid shape (bevel, 45°)	recesses of inverted rectangular prismoid shape (bevel, 45°)	recesses of inverted regular quadrangular pyramid shape (bevel, 25°)	microfine recesses and protrusions
Other surface (light entrance side)		microfine recesses and protrusions	flat	microfine recesses and protrusions	microfine recesses and protrusions
Total light transmittance	%	68.9	75.7	92.7	84.3
Haze	%	91.4	90.6	91.4	90.2
Luminance	cd/m^2	1890	1964	1876	1843
Dot-hiding property		○	○	○	○
Rumpling		none	none	none	none
Ra of light entrance side	μm	8.44	0.80	1.51	4.74

[0093]

It can be seen from Table 2 that the light diffusing films of Experimental Examples 4, 5, and 6 according to the invention and the light diffusing film of Comparative Example 3, which contain no light diffusing agent and have a single-layer structure, each have a haze of 90% or higher, which is satisfactory. There is almost no difference between the Experimental Examples and Comparative Example 3. With respect to luminance, however, the Experimental Examples are superior. Namely, as Table 2 shows, the luminances in the Experimental Examples are higher by as large as 33-121 cd/m^2 than that in Comparative Example 3. It can hence be seen that the light diffusing films which have recesses formed in the light emission side thereof (upper surface) have a better luminance than the light diffusing film having microfine recesses and protrusions and can be used to assemble a bright backlight unit. A comparison between Experimental Example 4 and Experimental Example 5 shows that the light diffusing film of Experimental Example 5 has a sufficient luminance and a sufficient total light transmittance although the lower surface thereof has no microfine recesses and protrusions.

[0094]

Fig. 12 shows that in the range of from 45° right to 45° left, the luminance of the light diffusing film of Experimental Example 4, which has recesses having the shape

of an inverted truncated regular quadrangular pyramid formed in a lengthwise/crosswise arrangement in the upper surface thereof and further has microfine recesses and protrusions randomly formed on the lower surface thereof, is higher by as large as 70-100 cd/m^2 than the luminance of the light diffusing film of Comparative Example 3, which has microfine recesses and protrusions randomly formed on each surface thereof. It can be seen from these results that in the range of from 45° right to 45° left, the light diffusing film of Experimental Example 4, which has recesses having the shape of an inverted truncated regular quadrangular pyramid formed in order, is superior in the property of condensing diffused light to the light diffusing film of Comparative Example 2.

[0095]

The following can be further seen from Fig. 11. The light diffusing film of Comparative Example 3 has a brightness peak of about 720 cd/m^2 at around 30°-40° right, whereas the light diffusing films of Experimental Examples 4, 5, and 6, in which recesses having the shape of an inverted truncated regular quadrangular pyramid or inverted regular quadrangular pyramid have been formed in order, have a brightness peak of about 850-950 cd/m^2 at around 30-40° right. It can be seen from these results that the light diffusing films of Experimental Examples 4, 5, and 6 each have a small brightness peak angle and a high luminance.

[0096]

To sum up, it can be seen from Table 2 and Figs. 11 and 12 that when the light diffusing films of Experimental Examples 4, 5, and 6 are incorporated into a backlight unit for liquid-crystal displays or the like, diffused light having a small brightness peak angle can be brought to the front direction by the lens film to thereby heighten the luminance of the liquid-crystal display screen.

[Brief Description of the Drawings]

[0097]

[Fig. 1] Fig. 1 is a diagrammatic sectional view of a light diffusing film (Example 1) according to one embodiment of the invention, and shows the light diffusing sheet incorporated in a backlight unit indicated by the imaginary lines.

[Fig. 2] Fig. 2 is an enlarged plan view illustrating part of the light diffusing film.

[Fig. 3] Fig. 3 is an enlarged sectional view illustrating part of the light diffusing film.

[Fig. 4] Fig. 4 is an enlarged sectional view illustrating part of a light diffusing film (Example 2) according to another embodiment of the invention.

[Fig. 5] Fig. 5 is an enlarged sectional view illustrating part of a light diffusing film (Example 3) according to still another embodiment of the invention.

[Fig. 6] Fig. 6 is an enlarged sectional view illustrating part of a light diffusing film (Example 4) according to a further embodiment of the invention.

[Fig. 7] Fig. 7 is a plan view illustrating another example of that surface of a light diffusing film in which recesses have been formed in order.

[Fig. 8] Fig. 8 is a plan view illustrating still another example of that surface of a light diffusing film in which recesses have been formed in order.

[Fig. 9] Fig. 9 is a graphic presentation showing the relationship between bevel in the upward/downward direction and luminance in light diffusing films.

[Fig. 10] Fig. 10 is a graphic presentation showing the relationship between bevel in the leftward/rightward direction and luminance in the light diffusing films.

[Fig. 11] Fig. 11 is a graphic presentation showing the relationship between bevel in the upward/downward direction and luminance in other light diffusing films.

[Fig. 12] Fig. 12 is a graphic presentation showing the relationship between bevel in the leftward/rightward direction and luminance in the light diffusing films.

[Description of Reference Numerals and Signs]

[0098]

10, 11, 12, 13 light diffusing film

2 one upper surface (light emission side)

3 recess

4 inclined face of recess

5 another lower surface (light entrance side)

6, 8 surface layer

20 lightguide plate

30 lens film

40 light source (cold cathode fluorescent tube)

θ bevel of inclined face of recess

d depth of deepest part of recess

t thickness of light diffusing film

[Designation of Document] Abstract

[Abstract]

[Problem]

To provide a light diffusing sheet 10 which enables the light from a lightguide plate 20 to be conducted to lens film after having been converted to diffused light having a small brightness peak angle, and which generates neither a moiré or interference fringe nor luminance unevenness, and is advantageous also from the standpoints of productivity and cost.

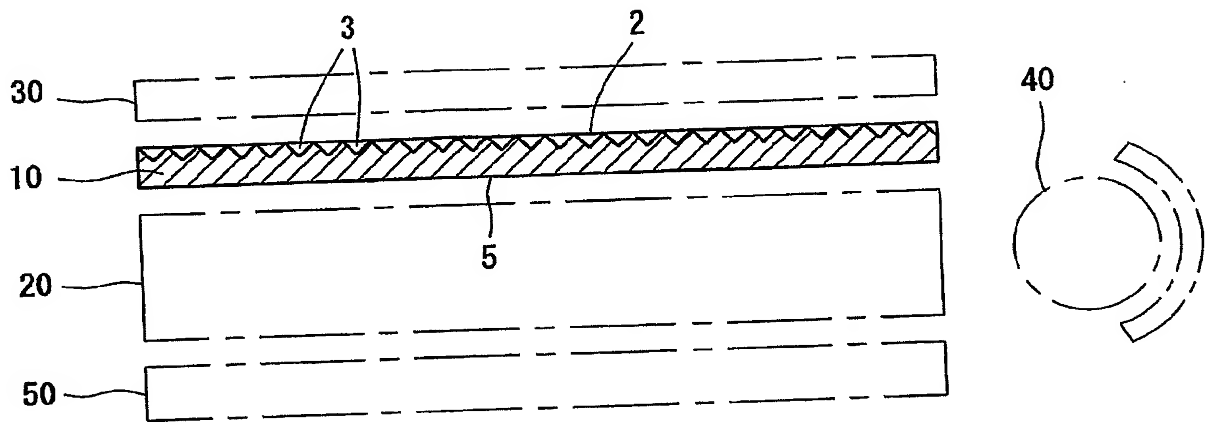
[Means for Solution]

The invention is composed of a light diffusing film 10 comprising a light-transmitting resin, characterized by having fine recesses formed in at least one of the surfaces 2 thereof, the fine recesses 3 having a shape which is any of the shape of an inverted polyangular pyramid, the shape of an inverted truncated polyangular pyramid, the shape of an inverted cone, and the shape of an inverted truncated cone. brightness peak angle of diffused light is reduced, which restrains both a moiré and interference fringe, according to light refraction due to inclined face of fine recess 3 or a taper face.

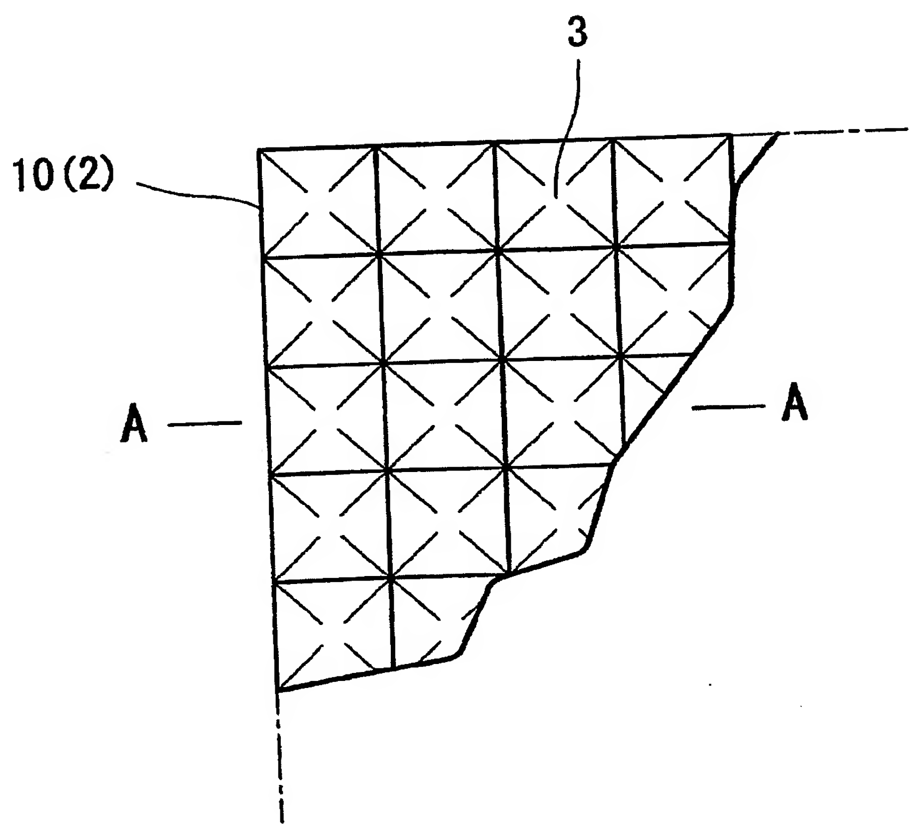
[SELECTED DRAWING] Fig, 1

【書類名】~~図面~~ Fig

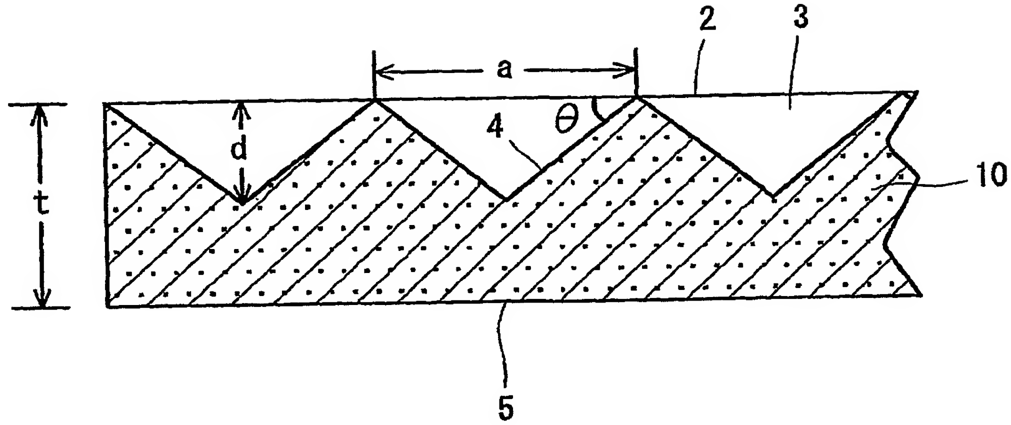
~~【図１】~~ Fig. 1



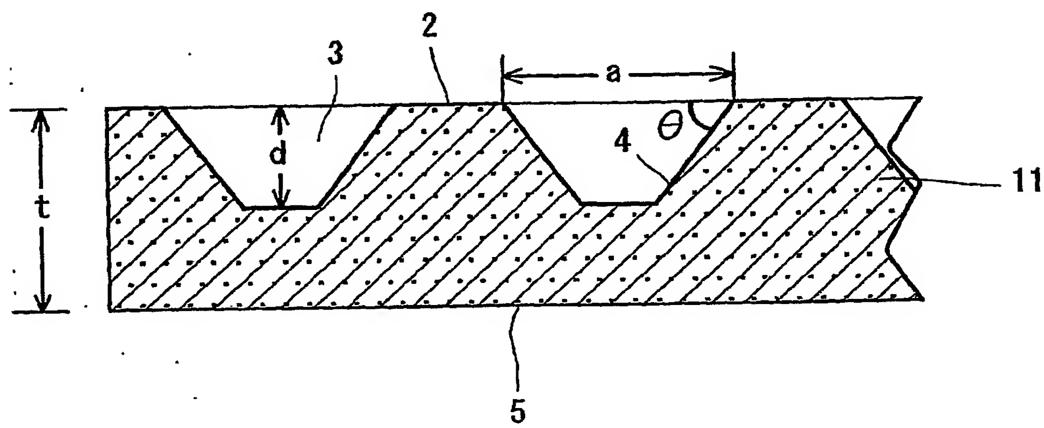
~~【図２】~~ Fig. 2



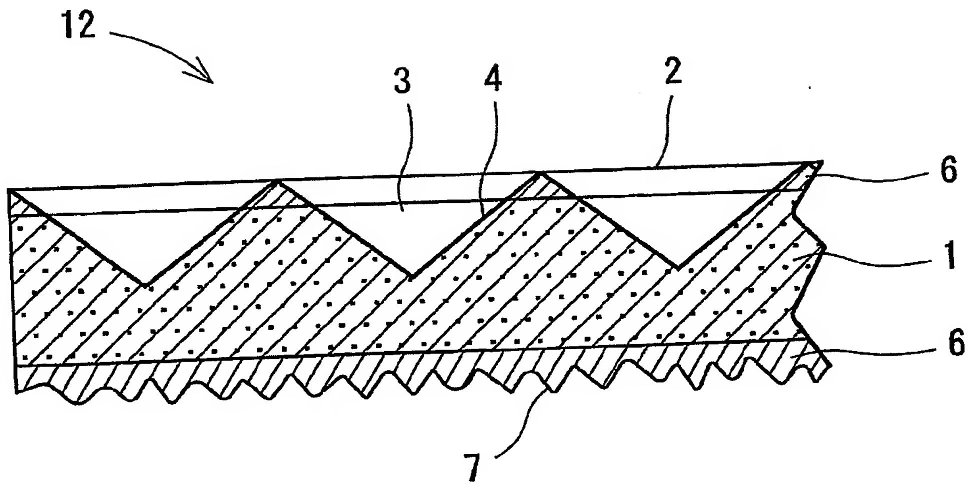
~~【図３】~~ Fig.3



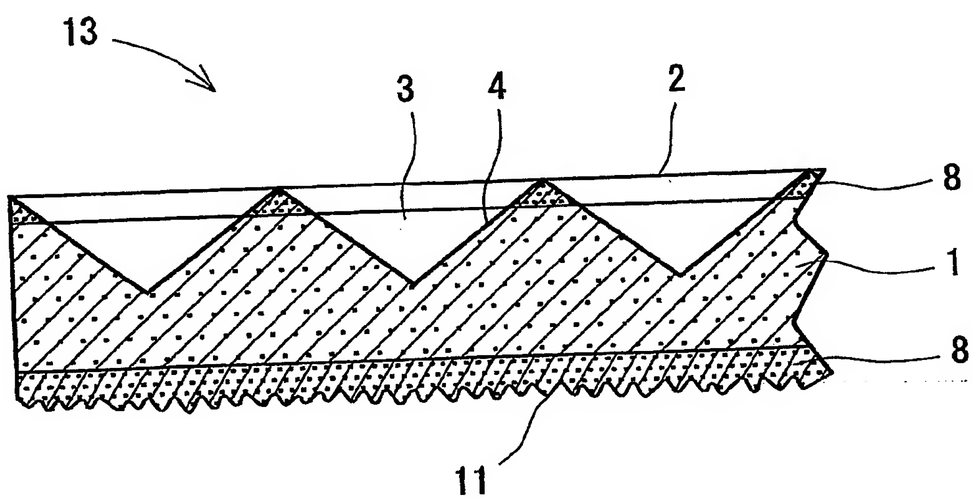
~~【図４】~~ Fig.4



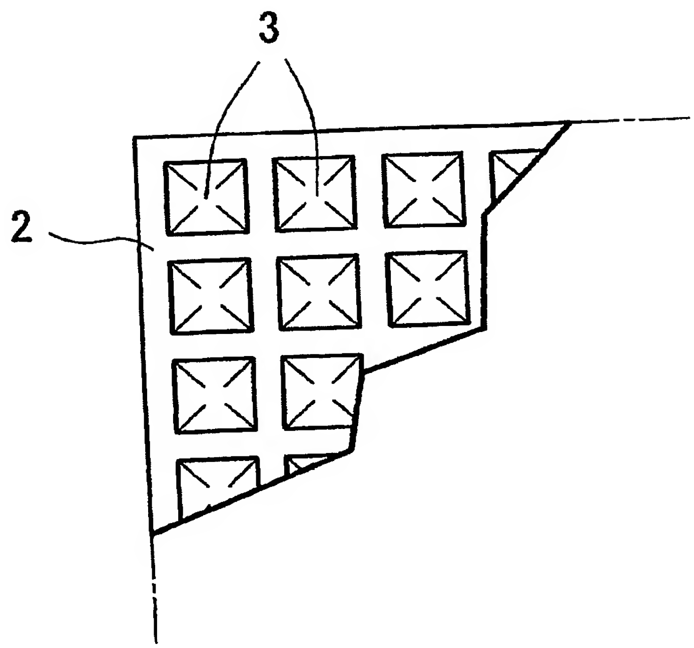
~~【図５】~~ Fig.5



~~【図６】~~ Fig.6



~~【図７】~~ Fig.7



~~【図８】~~ Fig.8

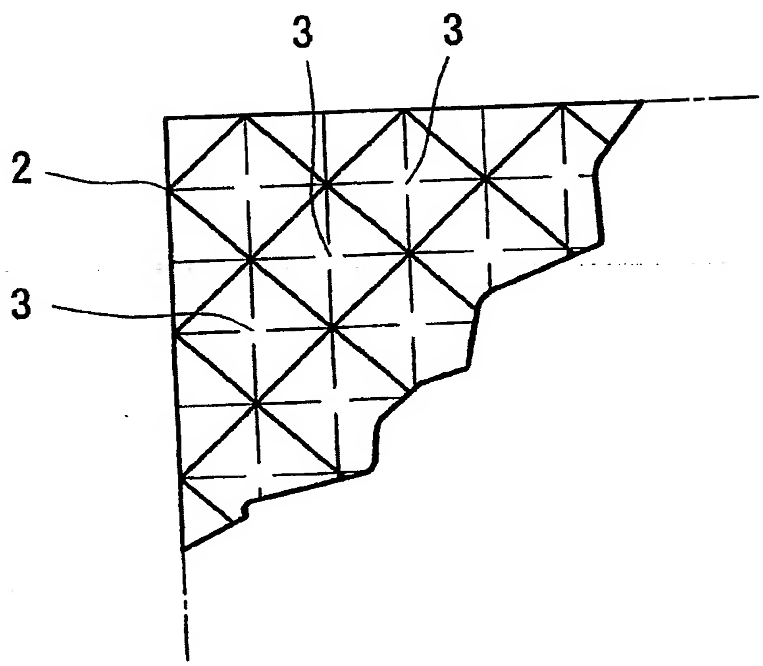


Fig. 9

~~【図９】~~

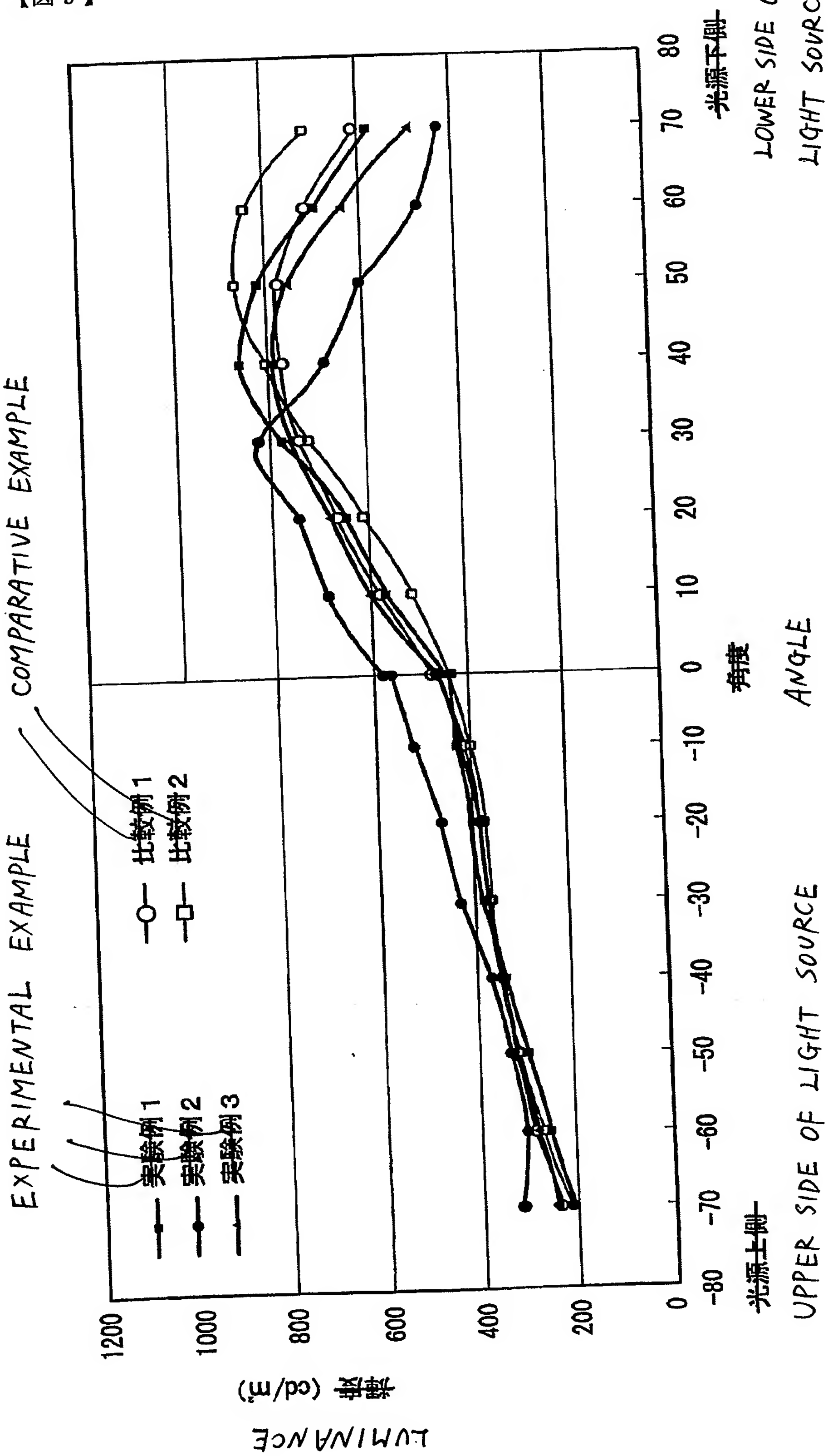
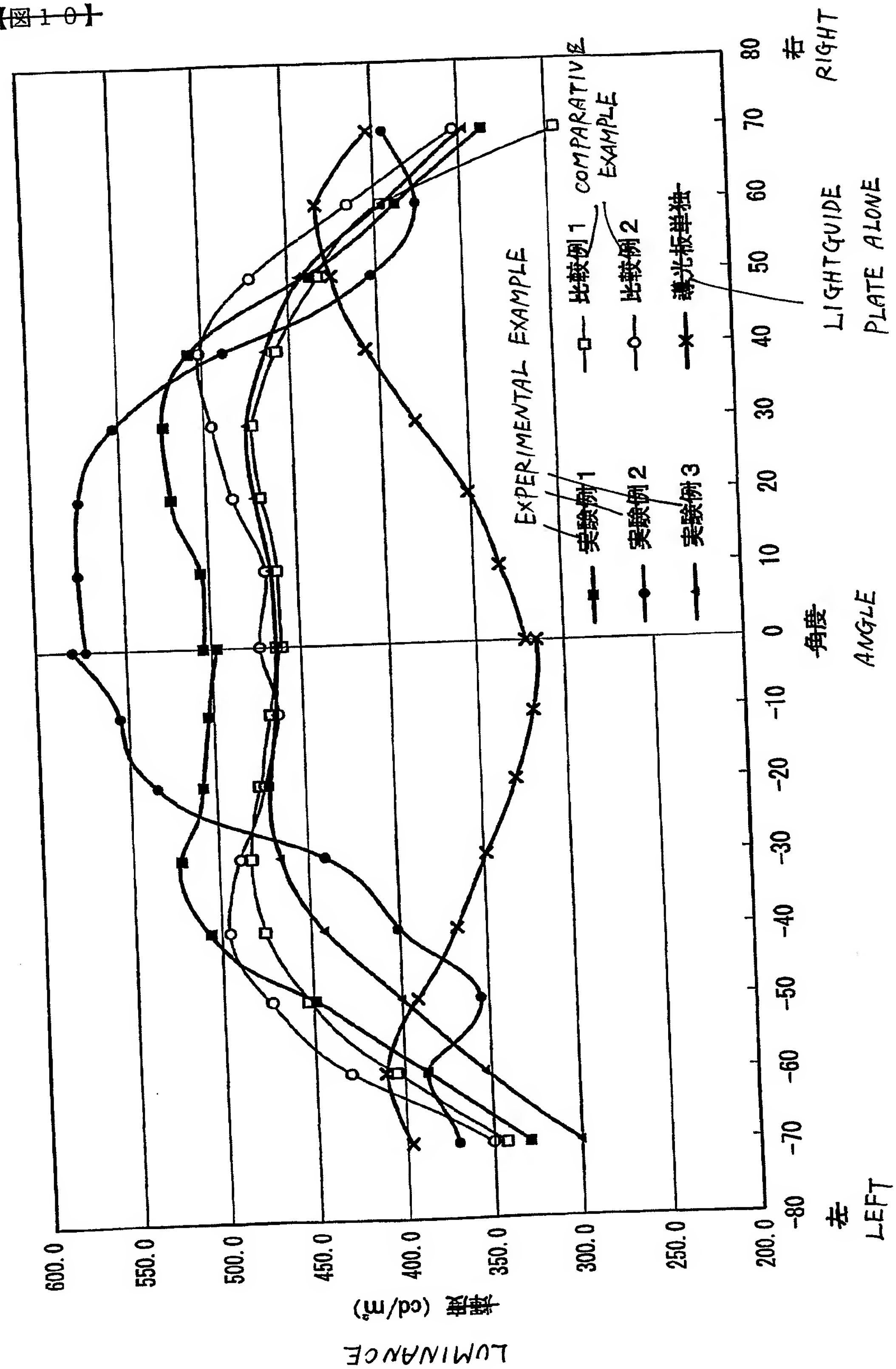
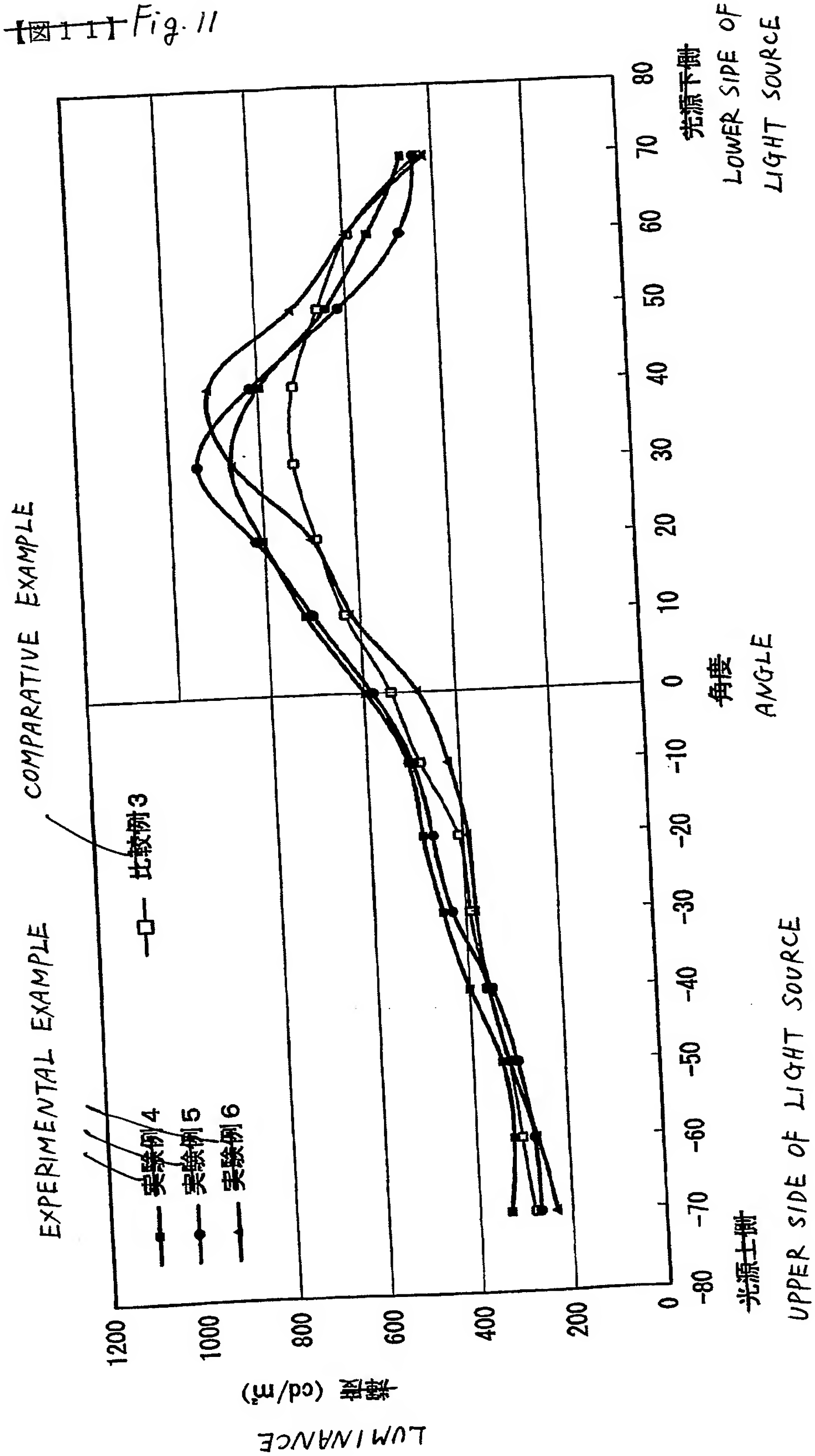

COMPARATIVE EXAMPLE
比較例１
比較例２
EXPERIMENTAL EXAMPLE
実験例１
実験例２
実験例３
輝度 (cd/m²)
LUMINANCE
1200
1000
800
600
400
200
0
-80
-70
-60
-50
-40
-30
-20
-10
0
10
20
30
40
50
60
70
80
角度
ANGLE
光源上側
UPPER SIDE OF LIGHT SOURCE
光源下側
LOWER SIDE OF LIGHT SOURCE

Fig. 10

~~【図１０】~~

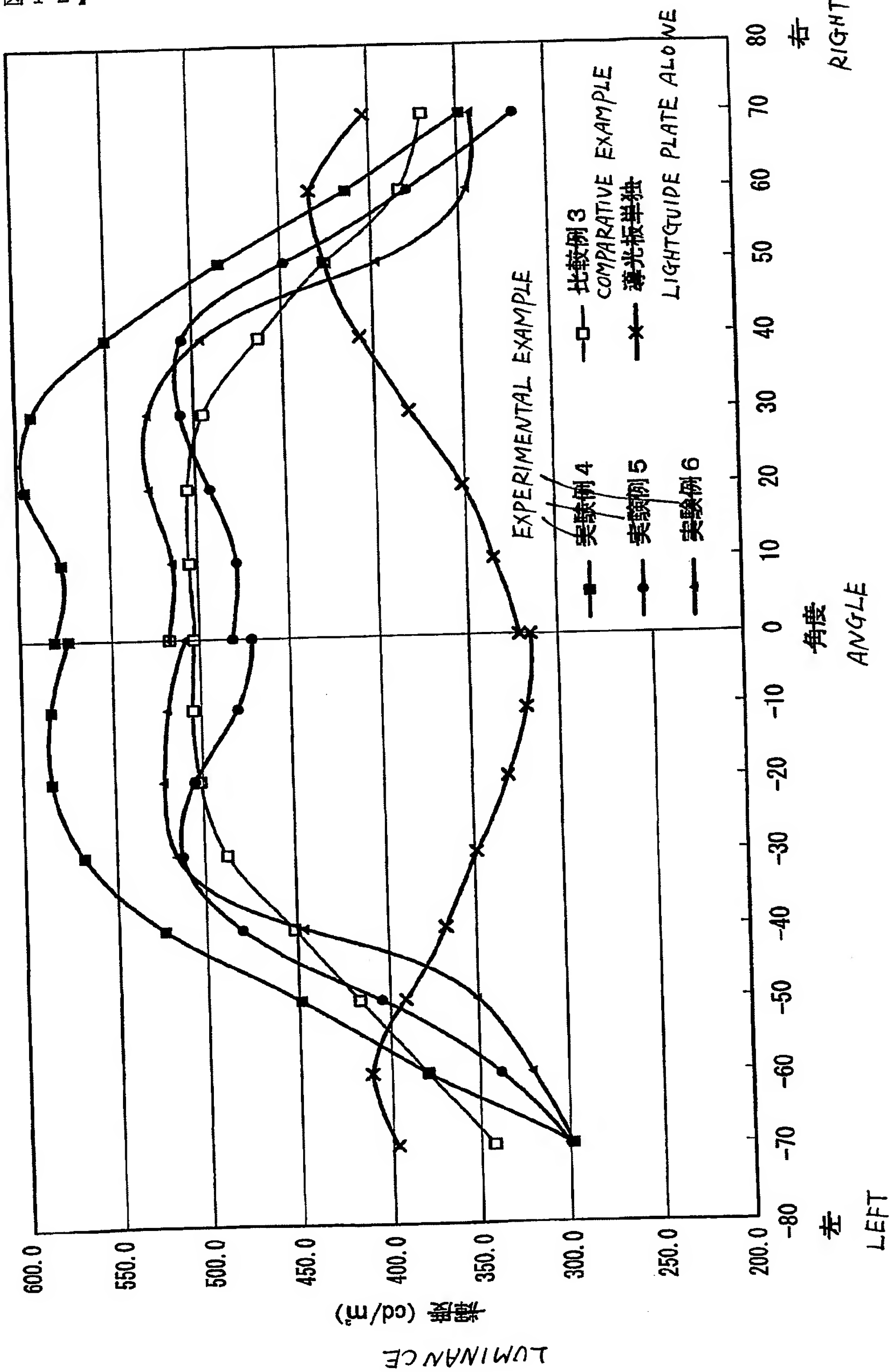

実験例１
実験例２
実験例３
EXPERIMENTAL EXAMPLE
比較例１
比較例２
COMPARATIVE EXAMPLE
導光板単独
LIGHTGUIDE PLATE ALONE
輝度 (cd/㎡)
LUMINANCE
角度
ANGLE
左
LEFT
右
RIGHT
600.0
550.0
500.0
450.0
400.0
350.0
300.0
250.0
200.0
-80
-70
-60
-50
-40
-30
-20
-10
0
10
20
30
40
50
60
70
80

~~【図１１】~~ Fig. 11



COMPARATIVE EXAMPLE
比較例3
EXPERIMENTAL EXAMPLE
実験例4
実験例5
実験例6
光源下側
LOWER SIDE OF LIGHT SOURCE
光源上側
UPPER SIDE OF LIGHT SOURCE
角度
ANGLE
輝度 (cd/m²)
LUMINANCE
1200
1000
800
600
400
200
0
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80

~~【図１２】~~ Fig. 12


比較例3
COMPARATIVE EXAMPLE
導光板単独
LIGHTGUIDE PLATE ALONE
EXPERIMENTAL EXAMPLE
実験例4
実験例5
実験例6
角度
ANGLE
右
RIGHT
左
LEFT
輝度 (cd/m²)
LUMINANCE
600.0
550.0
500.0
450.0
400.0
350.0
300.0
250.0
200.0
-80
-70
-60
-50
-40
-30
-20
-10
0
10
20
30
40
50
60
70
80